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LOCKHEED-GEORGIA COMPANY
Manufacturing Research Investigation

GMRI: 660.02

ABSTRACT

ESTABLISH THE GENERAL USE OF CERAMIC TOOLS IN PRODUCTION

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Ceramic tooling is now used to satisfy the requirements of cold forming and high temperature applications. Work during this period was concerned with molding dies, embedded element hot sizing tooling, layup blocks, and production improvement methods.

Three ceramic mold dies and three layup blocks are now used in production. The hot sizing die is now being modified after satisfactorily completing a large production order.

The release of fiberglass parts from the tool has been facilitated through the development of a pressure actuated air jet valve and an improved release agent.

CONCLUSION:

Ceramic molding dies, layup blocks, and hot sizing dies are capable of producing acceptable parts. Further development is needed to standardize tool fabrication and use techniques.

RECOMMENDATIONS:

Additional applications of ceramic tooling should be considered where heat distortion of conventional tools is a problem, and for reduction of tooling costs.

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LOCKHEED-GEORGIA COMPANY
Manufacturing Research Investigation

TO: All Concerned

REQUESTED BY: R. C. Stewart

PREPARED BY: C. M. Head

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DATE: 1-4-63
PAGE: 1 OF 27

INTERIM REPORT

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TITLE: ESTABLISH THE GENERAL USE OF CERAMIC TOOLS IN PRODUCTION .

BACKGROUND:

Ceramic tooling was introduced at Gelac during the recent Air Material Command contract work (AF 33(600)36888) and under GMRI 600.00, "Production Use of Ceramic Tooling". This assignment is aimed at establishing ceramic tooling for use on C-141 contracts where new tooling is needed and where a cost saving can be realized.

PROCEDURE AND RESULTS:

Production applications of ceramic tooling have been divided into five phases (1) fiberglass molding dies, (2) embedded element hot sizing tools, (3) hydroform blocks, (4) stretch form blocks, and (5) layup blocks. No evaluation of STFB's and HB's was accomplished during this period. An additional phase dealing with improvement of general tooling and production techniques was also added.

Phase I - Fiberglass Molding Dies

Three ceramic molding dies have now made production parts. These parts include the C-130 Window Reveal (P/N 340686), C-130 Litter Strap Box (P/N 346214), and C-141 Radar Junction Box Cover (P/N 3K10009).

Construction of the Window Reveal tool was described in GMRI 660.01. This platten heated tool was used to fill a production order of 175 fiberglass parts.

PROCEDURE AND RESULTS: (Continued)

During production several problems were encountered. Resin flowed into the "blow out valves", rendering them useless. Sticking of the formed parts necessitated the use of a parting agent. The standard agent, melted "Simonize", was used. However the "Simonize" built up in layers on the tool, and caused the part surfaces to be rough and unacceptable. Neither scraping nor chemical agents (ketone, naptha, and trichlorethylene) satisfactorily removed the wax layers. Prying of the sticking parts damaged the Glasrock tool. Neither patches of epoxy - rutile mixtures nor torch fused "Masrock"⁽¹⁾ adhered well to the tool. Failure of the patches left progressively larger holes. When damage became too severe the tool was removed from production (after running 175 parts). Tool damage in the early stages and wax buildup on the tool surface are shown in Figure 1.

Work on a replacement tool is planned for next quarter.

The Litter Strap Box tool was constructed with embedded heating elements. These elements consisted of two twisted strands of 19 gage Nichrome "V" wire. One half inch wire spacing was used in both punch and die. The tool was designed to operate with a power density of 25 watts per square inch each side and an input voltage of 220V.

The wires were chunked in a drill motor and twisted together. For use in the die section the strands were cut into strips of predetermined length and the strips were bent to the desired shapes. A long single strand was bent into a pseudo-coil for use in the punch. The wires were then dipped in molten beeswax. The beeswax was melted out after the tool was cast to provide room for thermal expansion of the heating elements.

The plaster models were boxed as shown in Figures 2A and B. The heating wires were suspended one half inch above the plaster face. An enlarged Teflon blowout valve was mounted in the boxed die mold for casting into place.

No provision for a blowout valve in the punch was made at this time, strictly due to an oversight. The Hydrocal plaster molds were laquered, waxed, and lightly wiped with peanut oil.

Norton Company's 33HD (calcium aluminate cement) was poured into the molds. The castings were internally vibrated to remove air bubbles from the mix. Care was required not to disturb the suspension of the heating wires.

The castings were dried at 250°F for 48 hours. Bubble holes on the tool surface were negligible and were filled with an epoxy-rutile mixture. A Teflon blowout valve was potted into the punch with the epoxy-rutile mixture. The tool surfaces were Teflon coated.⁽¹⁾

PROCEDURE AND RESULTS: (Continued)

Stainless steel guide pins were potted into the die, perpendicular to its base, using high temperature, non-filled epoxy. (Aluminum filled epoxy exhibits excessive thermal expansion). "Teflon" guide bushings were potted into the punch. Chromalox remote plug temperature controls (Catalogue No. AR 2534)* were connected independently, to punch and die. The exposed areas of the heating wires were protected with phenolic covers (see Figure 4).

Three phenolic kiss blocks were epoxy potted on the die block at the same time the bushings were potted in (see Figure 3).

The tool was mounted in the production press (D/18-06); toe clamps secured the punch to the ram. Approximately 15 minutes was required to heat the tool surface to 280°F. Complete temperature stabilization required three hours. The tool and sample parts are shown in Figure 4.

Superficial cracks appeared in the tool surface after heating. While they were reproduced in the part, they did not seriously interfere with part quality.

Numerous production problems were encountered. The blowout valves functioned while forming about 10 parts; thereafter the resin clogged them. Difficulty was observed in regulating the temperature of the punch and die so as to have the part remain in the die. The "Teflon" coating alone was incapable of providing easy part separation, and after about 10 parts a "Simonize" parting agent was used. Due to wax buildup and inadvertent damage, the tool was removed from production after forming approximately 375 parts.⁽¹⁾

A new blowout valve was developed and installed in the punch. A description of the valve appears in Figure 5. This valve worked well on ten sample parts formed in the laboratory press.

* Chromalox Controls, Edwin L. Wiegand Company, Pittsburgh, Pa.

PROCEDURE AND RESULTS: (Continued)

The Radar Junction Box cover tool was similarly constructed. The tool heating elements were twisted 16 gage strands; their configuration in the boxed mold is shown in Figures 6 and 7. The rod shown protruding above the center of the punch mold (Figure 7) was to provide a hole for insertion of a thermoswitch. A similar thermoswitch hole was provided in the die casting. The castable used with this tool was fused silica "Masrock".(1) The tool was heated to 1900°F to mature the cement. No cracking was observed when the tool was mounted in the press.

A Finwall* tubular cartridge type thermostat switch was cemented into the cavities provided for them in both punch and die. All connections were cemented (with "Masrock" - torch fused) into the tool and a Hubble plug was affixed to the sides of the punch and die.

A Junction Box cover tool was also made of 33 HD cement and was designed to be platten heated. The "Teflon" coated tool is shown in Figure 8. Cracks appeared in the working surface and in the corners when the tool was tested in the press. The damaged corners required recasting. The recast corners also failed and were strapped into position with steel bands. Additional corner support was provided by coating the tool sides with tooling epoxy.

A bad feature of both tools was encountered when forming sample parts. Lowering the punch squeezed the resin out of the matt in the corners of the part. The resin - deficient corners broke on handling and were unacceptable. The corners of the punch were ground slightly to reduce the tightness of the fit. Satisfactory parts were then formed.

The platten heated tool was used to form a production order of seven parts. Evaluation of the embedded element tool is still in process.

Phase II - Embedded Element Hot Sizing Tooling

A new Glasrock punch and die were made to further evaluate this type of tooling. This new tool differed from the old tool, described in GMRI 660.01, mainly in the heating elements. These elements consisted of single strands of 16 gage Nichrome "V" wire bent to the proper contour. The punch, however, broke during the firing cycle and was replaced by one using the old method of two 19 gage wires twisted together.

A second innovation was the addition of a locating pin in the punch to assure proper seating of the preformed part on the hot sizing tool. This pin was first machined from Lava "A",** but it proved to be too brittle and was replaced with an AISI 420 steel pin. No allowance was made for the thermal expansion of the pin, but this had no detrimental effect on the tool.

* Finwall, Inc., Ashland, Mass.

** A product of American Lava Corporation, Chattanooga, Tennessee

PROCEDURE AND RESULTS: (Continued)

The new tool was evaluated on a production order of 77 parts. Figure 9 is a photograph of the tool in the press during the production run. At the completion of the order, tool wear was evident in several places. The punch had a large chip in the back flange, (see Figure 10). Both of the beads in the die were broken, one before (due to faulty handling) and one during the production run. Also, one entire side of the die (female) had cracked. None of these defects adversely affected the part quality as they were "out of part".

The parts produced by this tool failed to have the wrinkle left by the preform operation on the Bliss hydropress removed. A forming pressure of 125 psi at 1000°F was found to be adequate to hot size the parts. Trials at higher pressures did not improve the wrinkle situation.

The lubricant used was a mixture of milk of magnesia and molybdenum disulfide. This lubricant, which was applied directly to the punch and die as required, left a progressive build-up on the tool and probably contributed to cracking of the die. Since the completion of the production run, several commercial high temperature lubricants have been evaluated, the most promising being a water and graphite mixture applied to the preformed part before it is placed on the hot sizing tool.

The punch has been repaired by methods indicated in previous reports, and the die replaced. Several important changes have been incorporated in the new die. First, the tool has been encased in a steel box. It is felt that if the die should crack on a future production order, the box would hold the parts of the die in their places. In addition, the box has simplified the procedure of attaching the tool to the die set. Second, the heating elements were welded together before the new die was cast. In this manner, the joints are no longer exposed to the air. Third, the size of the bead on the die was increased to its maximum tolerance limit to aid in the removal of the wrinkle left by the preform operation. The top of the beads have also been rounded to prevent their frequent breakage. Figures 11A and B are photographs of the new die.

The repaired punch and the new die will be tested on a new production order. If the tools prove satisfactory, a back-up tool will be constructed incorporating all improvements made to date.

Phase III & IV - Hydroblocks and Stretch Form Blocks

No work was done on either HB's or STFB's during this period.

PROCEDURE AND RESULTS: (Continued)

Phase V - Layup Blocks

Three ceramic layup blocks are now used in production. They are used in forming part number 360631 (C-130 Radio Compartment Liner), part number 3K10008 (C-141 Radar Junction Box), and part number 3B10367 (C-141 Power Assembly Cover).

The Radio Compartment mold was plastic coated plaster. A styrofoam core was suspended in the mold three inches from the mold sides. The castable used was Special Hi Alumina cement* (calcium aluminate). The casting was internally vibrated. After drying at 300°F for 60 hours the core was chipped out.

The casting and mold are shown in Figure 12. A closeup of surface bubble holes in this casting is shown in Figure 13. These holes were prevalent on vertical surfaces only.

The holes in the tool were patched with an epoxy - rutile mix and the tool was "Teflon" coated.

Operators in the Plastic Shop, Department 18-06, requested that a six inch buildup be added to the base of the casting. The buildup provided extra layup area and facilitated part trimming.

The tool was potted to a phenolic base with semi-flexible tooling epoxy. An air vent from the hollow interior was provided by running a copper tube from the cavity to the edge of the phenolic. The air vent prevented excessive pressure buildups in the void.

The layup block is shown in Figure 14.

Relative flexibility of the phenolic base and poor abrasion resistance made the LUB base plate unsatisfactory. The LUB was broken from the plate during part removal. It was repotted to an aluminum plate and was bolted to the plate with small angles.

The ceramic LUB was used to form approximately 55 parts of a production order of 80. The remainder of the order was filled using a tooling plastic LUB. The two blocks were used simultaneously. The difference in output was due to cracking of the plastic LUB due to thermal expansion while part curing. The ceramic block has since formed approximately 70 parts on a second production order.

* Product of General Refractories Company, Philadelphia, Pa.

PROCEDURE AND RESULTS: (Continued)

A second hollow tool was constructed with a "Masrock" shell backed with fused silica foam. The tool was weak structurally and was irreparably damaged in handling. A replacement was not constructed.

The Junction Box tool was cast on a plastic coated, plaster model; the castable used was Norton Company's 33 I, alumina bubble, calcium aluminate cement. This castable was used because of its low heat absorption. The tool was "Teflon" coated and potted to a magnesium plate with a semi-flexible epoxy. Only two production parts were formed on this tool.

The Junction Box LUB was the tool used in the following pictorial series (Figures 15 - 25) describing the layup process.

A layup block to form part 3B10367 (Power Assembly Cover) was constructed in the same manner as the above tool. This tool, however, was potted to a steel plate. Seven production parts have been formed on this tool. The LUB is shown in Figure 26.

Phase VI - Tooling and Production Improvement Techniques

Investigations have been conducted covering a variety of subjects. Among these are new ceramic castable compositions, tool-part release agents, interference proof blowout valves, and a vibrating table.

A new hydraulic setting, fused silica castable developed by Glasrock Products, Inc. was evaluated. Six standard bricks (9" x 4 1/2" x 2 1/2") were cast with the material and were allowed to set up over night. The bricks were dried at room temperature for three days; three were further dried at 300°F for 24 hours. The modulus of rupture of each sample was determined.⁽²⁾ The average modulus of rupture of the air dried brick was 588 psi; the average modulus of the heat dried brick was 900 psi.

Bubble holes on the working surfaces of cast ceramic tooling have been particularly troublesome. Such holes were prevalent on vertical surfaces of the tools. While internal vibration tended to reduce the number of bubbles in the casting⁽¹⁾, it was impractical to use in casting embedded element tools.

To facilitate bubble removal from castings a large, variable frequency vibrating table was constructed. The steel table had a working area of 48" x 80" and a nominal load limit of 1000 pounds. An eccentric weight type mechanism produced sinusoidal table movement and permitted frequency variation from 0-60 cycles/sec. The mechanism was driven by 1.5 hp motor. The vibration amplitude was adjustable (within limits) being dependent on the load.

The vibrating table and console are shown in Figure 27.

PROCEDURE AND RESULTS: (Continued)

Several methods of filling bubble holes in castings were evaluated. These included calcium aluminate fines (-100 mesh) plus water, tooling epoxy, epoxy-rutile mixtures, fused silica slip-colloidal silica - calcium aluminate mixtures, and Savereisen cements.* Only Savereisen cement number 31 and epoxy rutile mixtures (where the rutile is present in amounts greater than 50% pbw) were found satisfactory. The latter mixture tended to distort slightly at temperatures above 300°F. The other mixtures did not adhere well and were pulled away during removal of plastic parts.

Two tool-plastic part release agents were evaluated: (1) a mixture of Dow Corning Sylgard 182 (silicone varnish 1 pbw) - naptha (20 pbw), and (2) a mixture of resin release "N"**(1 pbw) - Naptha (10 pbw). The resin release "N" mixture provided excellent part separation from the tool, but the part surface tended to be rough. The silicone varnish solution gave excellent part separation without roughening the part. The silicone varnish solution is now in production usage.

A pressure actuated air jet valve was developed for use in molding dies to facilitate plastic part removal. This valve cannot be blocked by resin flow under hydraulic pressure when the molding die is closed. The valve is easily potted or cast flush with the working surface of the tool. A description of the valve is shown in Figure 27.

* Savereisen Cements Company, Pittsburg, Pa.

** Specialty Products Company, Jersey City, N. J.

ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION

GMRI: 660.02
PAGE: 9

TABLE I

SUMMARY OF TOOLS IN PRODUCTION* OR UNDER CONSTRUCTION

AIRPLANE	PART NUMBER	PART NAME	TOOL CODE	TOOL NO.	STATUS	REMARKS
C-130	388123-1	Access Door Skin	STFB	2	Legal tool made 4 parts on tool try	Reported in GMRI 600.00
C-140	JF391-6	Cabtop Skin & Doublers	HB	1	Right & Left Hand tools - 73 parts made on each	GMRI 600.00 GMRI 660.01
C-130	340686-3	Window Reveal	MD	2A	Made 250 parts before scrapping	GMRI 600.00
				2B	Made 175 parts before scrapping new tool planned next quarter	GMRI 660.01 GMRI 660.02
C-130	354759-1	Flap Carriage Baffle	X	1A	Made 86 parts before scrapping	GMRI 600.00
				1B	Made 77 parts - die was scrapped	GMRI 660.01
				1C	Tool consists of new die & repaired 1B punch. Now being used on production order	GMRI 660.01 GMRI 660.02
C-130	354759-1	Flap carriage Baffle	HB	1A	Made 86 parts before scrapping	GMRI 660.01 GMRI 721.01
				1B	Made 77 parts	No description
				2	Awaiting tool try	awaiting tool
				3	Awaiting tool try	try result of series 1B-3
C-130	346214	Litter strap Box	MD	2	Made 375 parts	GMRI 660.02
C-130	360631	Radio Compartment Liner	LUB	2	Made 125 parts - tool damage	GMRI 660.02
				3A	irreparably in handling. Under construction -	GMRI 660.02
				3B	Awaiting plaster mold	

ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION

GMRI: 660.02
PAGE: 10

TABLE I (Cont'd)

SUMMARY OF TOOLS IN PRODUCTION* OR UNDER CONSTRUCTION						
AIRPLANE	PART NUMBER	PART NAME	TOOL CODE	TOOL NO.	STATUS	REMARKS
C-141	3K10008	Radar Junction Box	LUB	2	Made 7 Parts	GMRI 660.02
C-141	3K10009	Radar Junction Box Cover	MD	1	Made 7 Parts	GMRI 660.02
C-141	3B10367	Power Assembly Cover	LUB	1	Made 7 Parts	GMRI 660.02
C-141	3B10366	Emergency Power Box	LUB	1	Awaiting Engineering Change	
C-141	3E22121	Waste Water Tank	LUB	1	Tool made in 2 sections, under construction	
C-141	3E22128	Access Door Plumbing	LUB	1	Under Construction	
C-141	3K14081	Intercom Jack Cup	MD	2	Under Construction	

X No Gelac tool code - tool is a hot sizing die

* All tools still in production unless otherwise specified.

CONCLUSIONS:

Phase I - Molding Dies

1. The time required to heat a molding die to working temperature is considerably lessened through the use of embedded heating elements.
2. Both fused silica and calcium aluminate castables are suitable materials for fiberglass molding die construction.
3. A Teflon coating alone on the working surfaces does not eliminate part sticking.
4. Interference - free blowout valves facilitate prompt part removal.

Phase II - Embedded Element Hot Sizing Tooling

1. The tool is capable of producing satisfactory parts, however part wrinkling must be removed by hand working.
2. Noticable, but repairable, wear is evident after large production orders.

Phase V - Layup Blocks

1. Production performance data is insufficient to make definite conclusions. However current performance indicates tool damage induced by thermal expansion is negligible in comparison with that of a plastic LUB.

Phase VI - Tooling and Production Improvement Techniques

1. Sauereisen cement No. 31 is the most satisfactory material found to date for patching bubble holes in calcium aluminate castings.
2. A silicone varnish - naptha solution provides excellent part release without roughening part surfaces.
3. An interference - free blowout valve facilitates part separation.

RECOMMENDATIONS:

1. Investigations to simplify embedded element tool fabrication and to reduce tool wear should be conducted.
2. Further use of fused silica and calcium aluminate molding dies should be considered where heat distortion of conventional tools is a problem.
3. Further data on tool life of ceramic layup blocks should be obtained.

ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION

GMRI: 660.02
PAGE: 12

REFERENCES:

1. Report - GMRI 660.01, "Establish the General Use of Ceramic Tools in Production".
2. Report - GMRI 434.00, "Non-Metallic Tooling For High Temperature Applications", AMC Technical Report 61-7-669, March 1961

PATENTS:

A "Disclosure of Invention" has been initiated to cover the pressure actuated air jet valve.

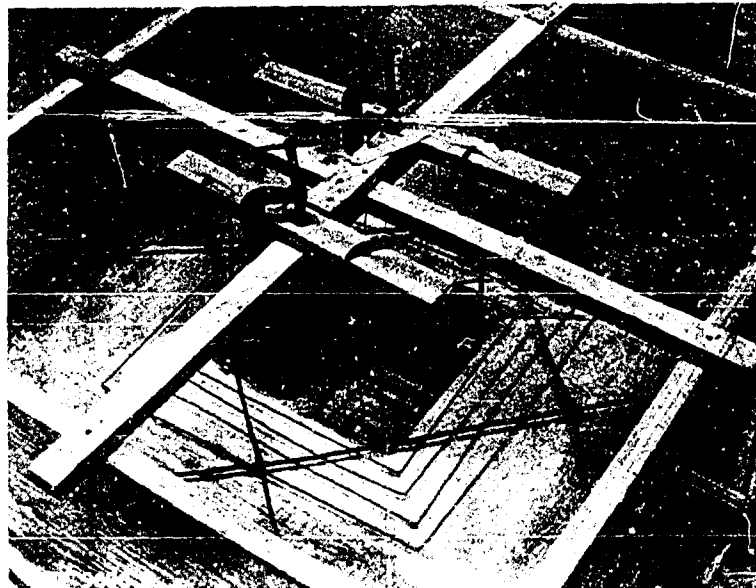
ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION



RF 9316 1

Fig. 1

Close up of reveal die punch, showing chipping and wax buildup on surface. (Pictures of the overall tool are included in GMRI 660.01).

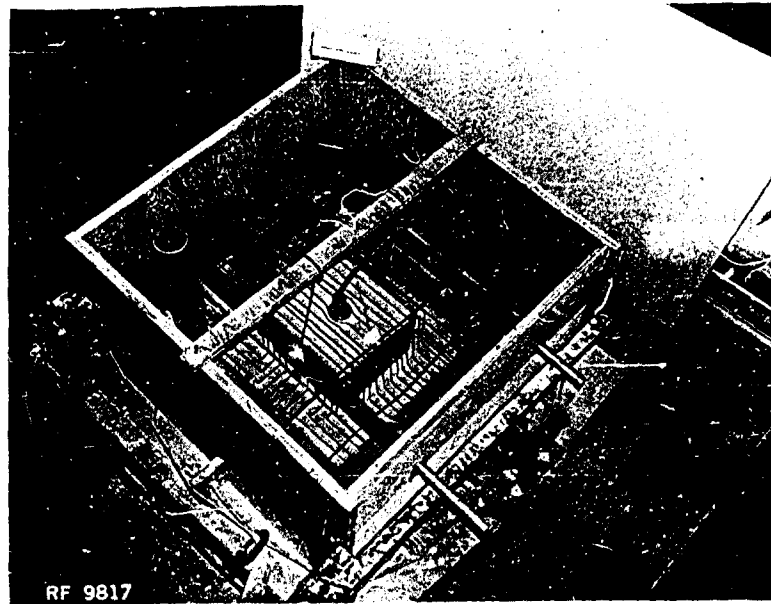


RF 9696 3

Fig. 2A

Heating element suspension prior to casting punch section of Litter Strap Box tool.

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CERAMIC TOOLS IN PRODUCTION

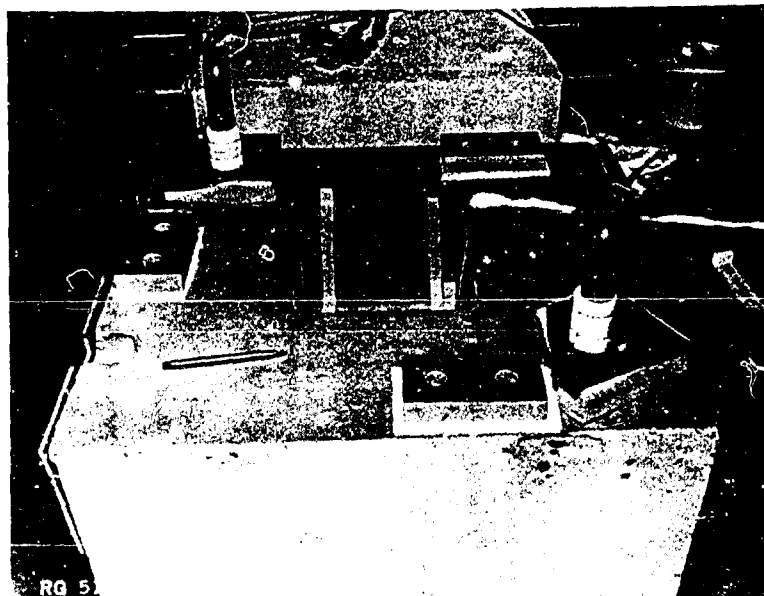


RF 9817

RF 9817

Fig. 2B

Nichrome wire configuration in Litter Strap Box die section. Wires were suspended above the plaster mold with thread.



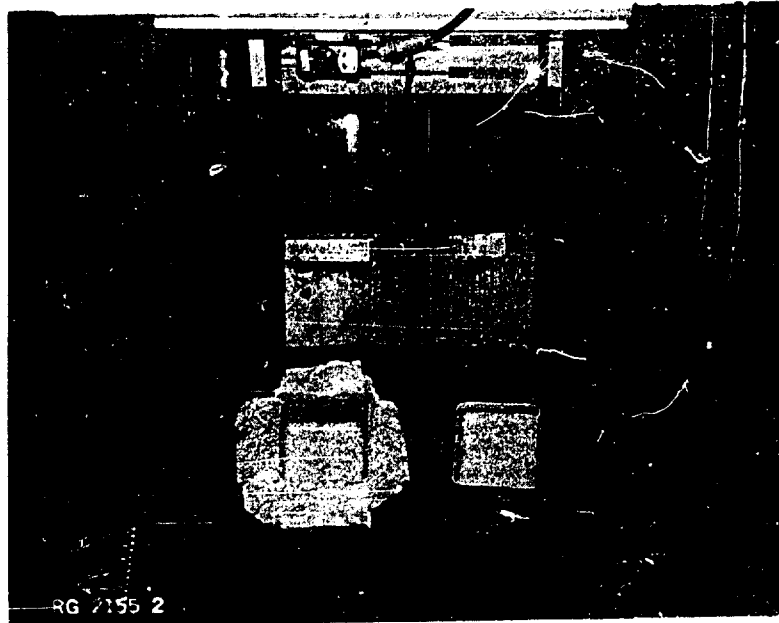
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RG 519 5

Fig. 3

Setup for potting kiss blocks and Teflon guide bushings. Epoxy was puddled under kiss blocks which were positioned on picture frame of resilient plastic foam, punch was cradled, and then guide bushing potting poured.

ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION



RG 2155 2

Fig. 4

Litter Strap Box tool in press. Both an unfinished and a trimmed part are shown.

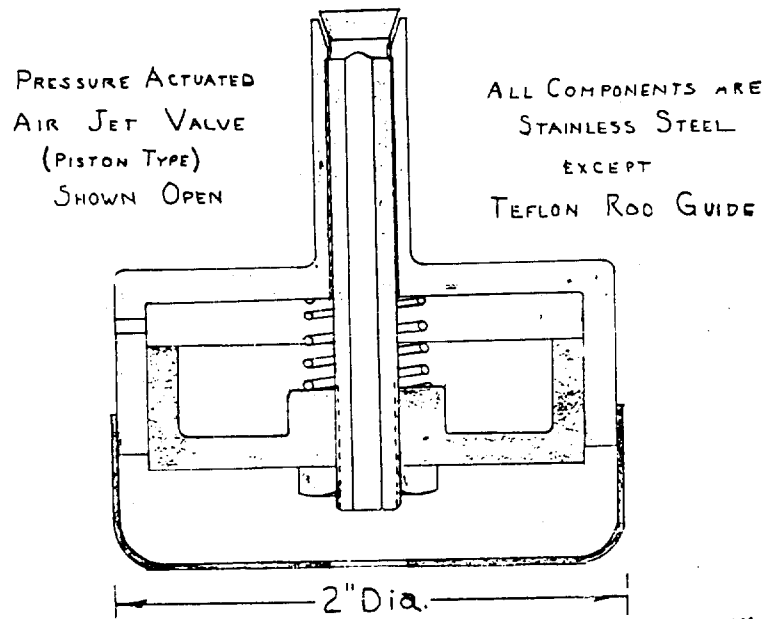
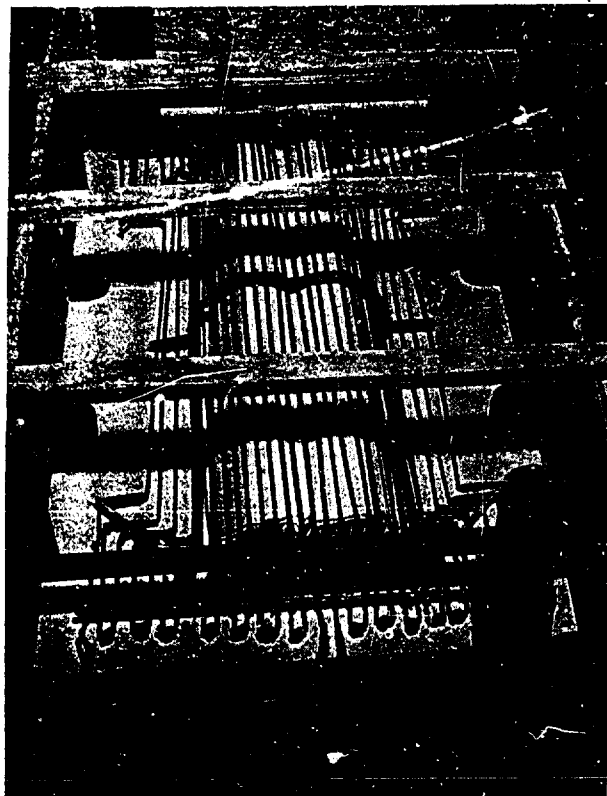


Fig. 5

Drawing of valve assembly used in Litter Box.

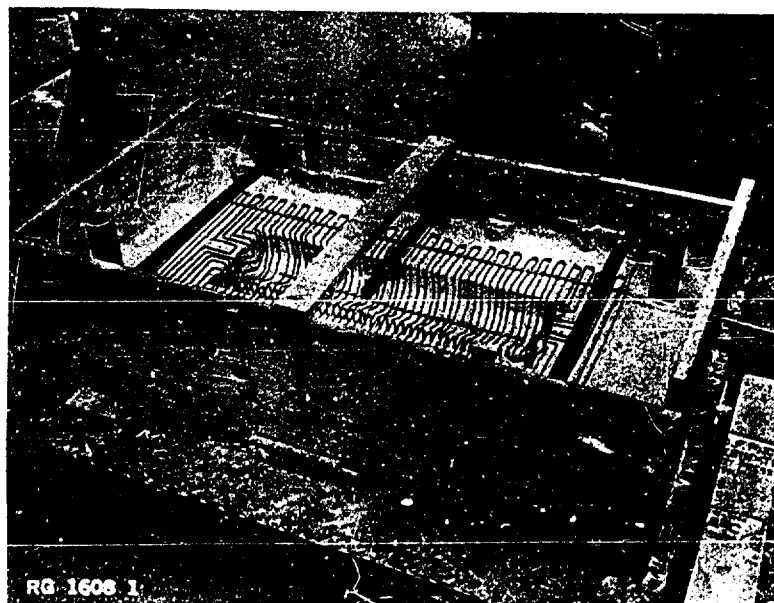
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Mold and heating wire
assembly prior to
casting Radar Junction
Box cover (die).

RG 1826-2

Fig. 6

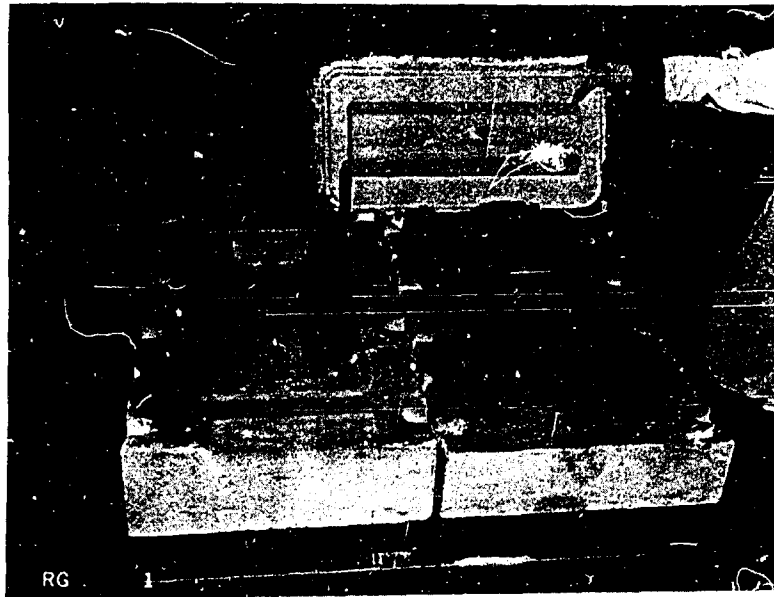


RG 1608 1

Fig. 7

Box mold assembly of Radar Junction Box cover
(punch). Phenolic rod in the center provides for
thermoswitch installation.

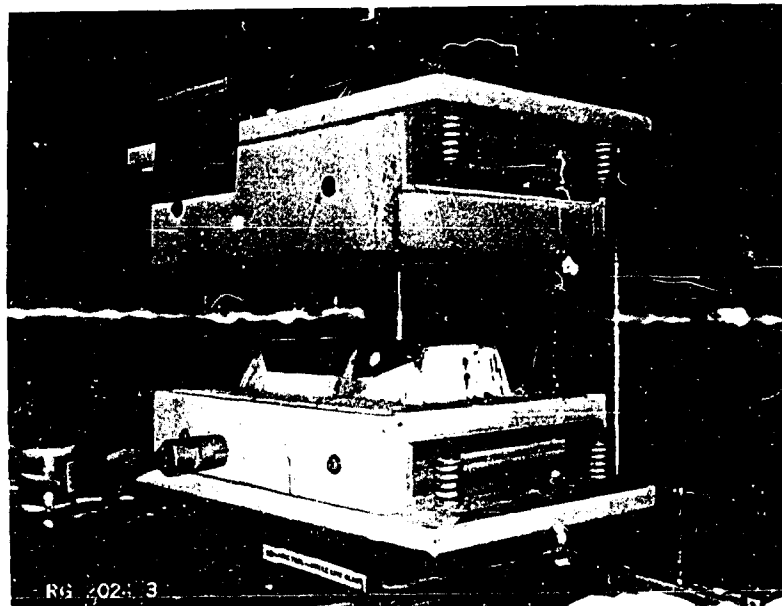
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CERAMIC TOOLS IN PRODUCTION



RG 2155 1

Fig. 8

Finished Radar Junction Box Cover tool and sample part (untrimmed).

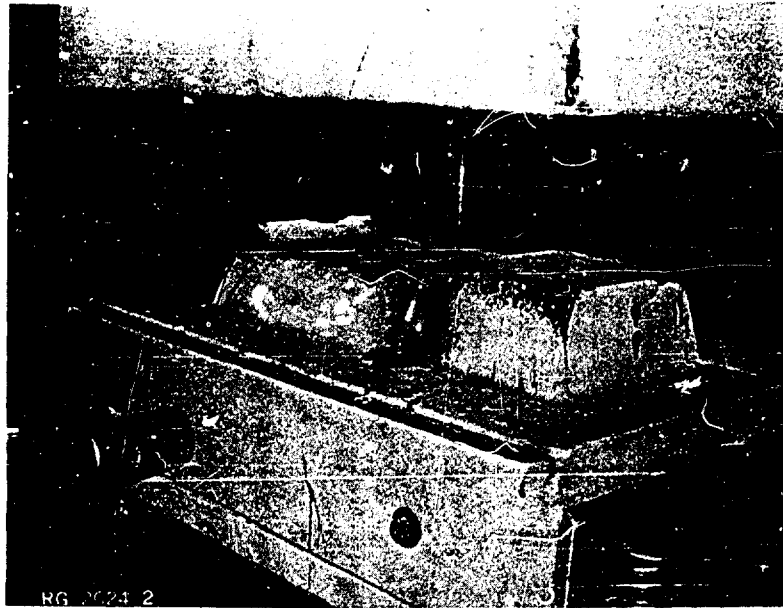


RG 2024 3

Fig. 9

Embedded element hot sizing die mounted in production press.

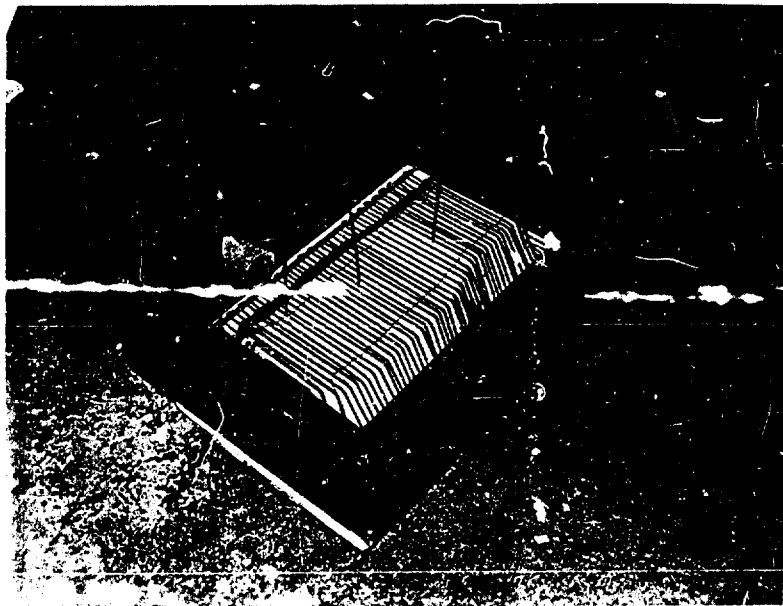
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CERAMIC TOOLS IN PRODUCTION



RG 2024 2

Fig. 10

Punch section at completion of production order.
Chipping and parting agent buildup are evident.

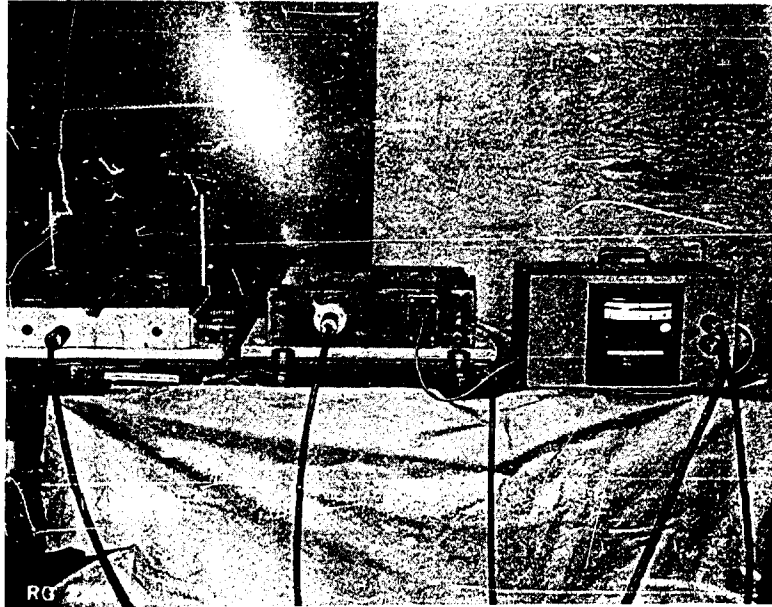


RG 2036 1

Fig. 11A

Steel box and heating elements on mold in
preparation for casting.

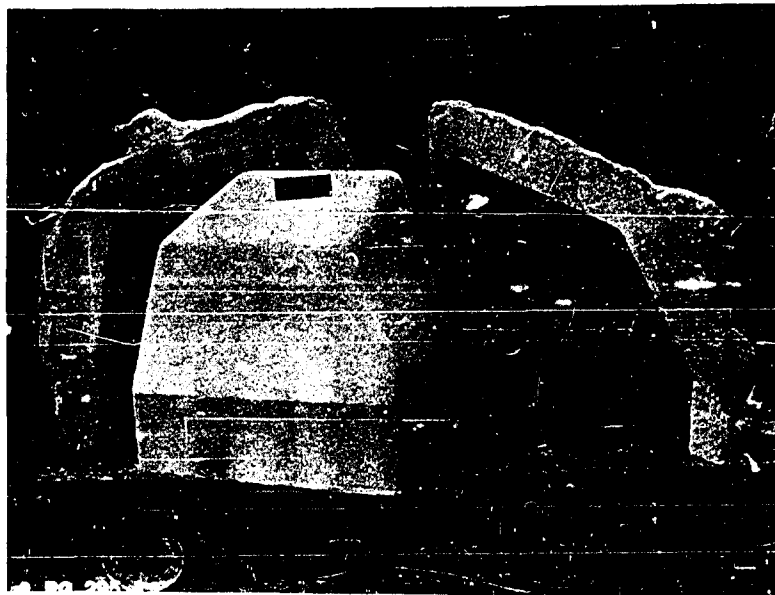
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RG 2201 1

Fig. 11B

Finished hot sizing tool with temperature controller.
Only the die is boxed.



RG 295 1

Fig. 12

Mold and casting of Radio Compartment tool.

ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION



RG 295 8

Fig. 13

Bubble holes on surface of Radio Compartment LUB casting.



RG 658 2

Fig. 14

Finished Radio Compartment LUB, potted to phenolic base.

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RG 2076 1

Fig. 15

Thalco parting agent solution is sprayed over working surfaces. The Thalco dries to a film after 10 minutes at 250°F. A coating of Simonize wax is applied over the Thalco film.



RG 2076 3

Fig. 16

Resin impregnated cloth is laid on the tool and the wrinkles removed.

ESTABLISH THE GENERAL USE OF
CERAMIC TOOLS IN PRODUCTION

RG 2076 4

Fig. 17

The bottom of the tool is cleaned with Naptha and a Chromate-putty strip is applied around the bottom. Two layers of felt stripping is wrapped about the tool just inside the puttied area.



RG 2076 5

Fig. 18

A sheet of PVA (polyvinyl alcohol) is laid over the LUB and wrinkles removed. The sheet is held down by the putty ring. Additional putty is applied to help form an airtight PVA bag.

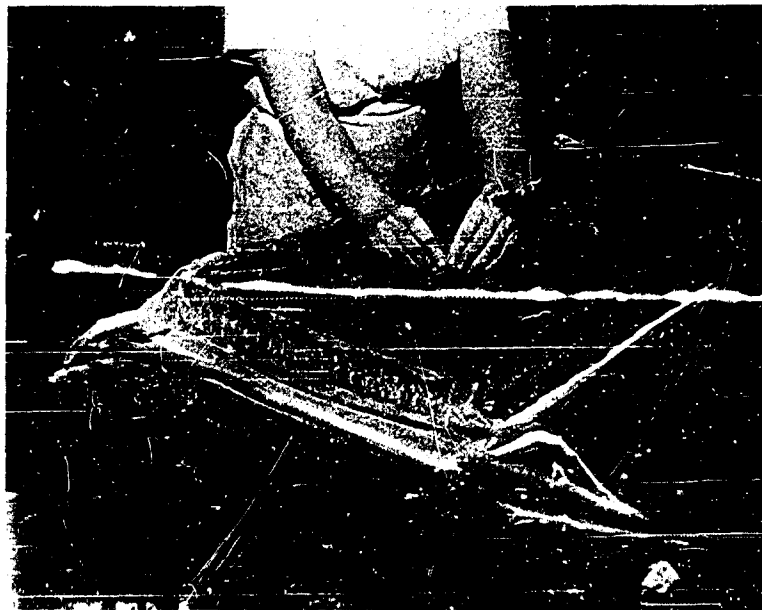
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CERAMIC TOOLS IN PRODUCTION



RG 2076 7

Fig. 19

A vacuum is pulled in the bag.

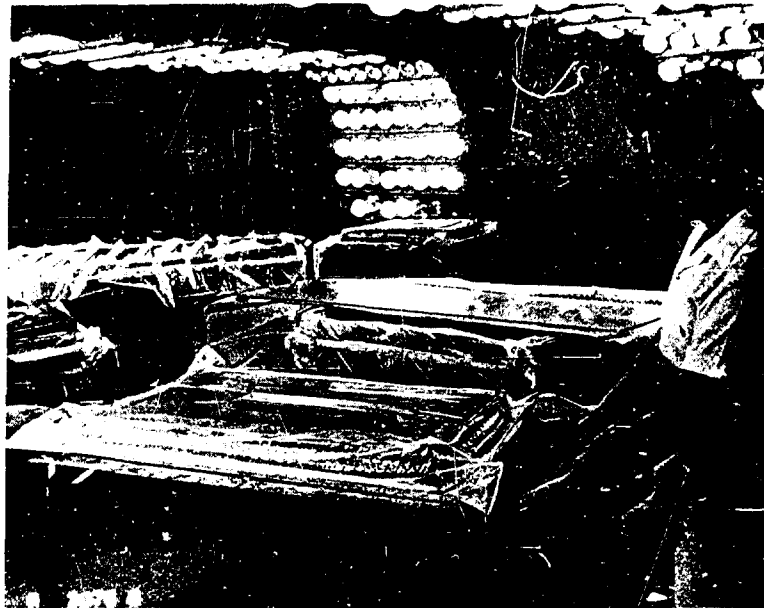


RG 2076 6

Fig. 20

A small spline is used to remove wrinkles from the
bag and to lay the cloth flat.

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CERAMIC TOOLS IN PRODUCTION



RG 2076 8

Fig. 21

The part is cured under heat lamps. Temperature is approximately 250°F; curing time is about an hour.



RG 2076 9

Fig. 22

After the curing cycle the bag is cut and pulled away.

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CERAMIC TOOLS IN PRODUCTION



RG 2076 10

Fig. 23

The part is removed from the tool with the aid of phenolic scrapers and compressed air.

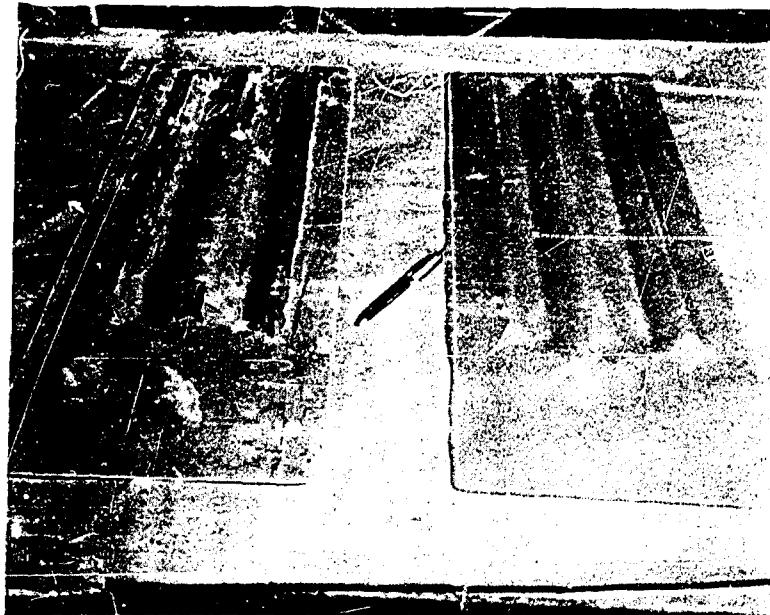


RG 2076 11

Fig. 24

The part is then trimmed to required dimension. Trimming is usually done with a trim fixture and a router, though use of a band saw is acceptable.

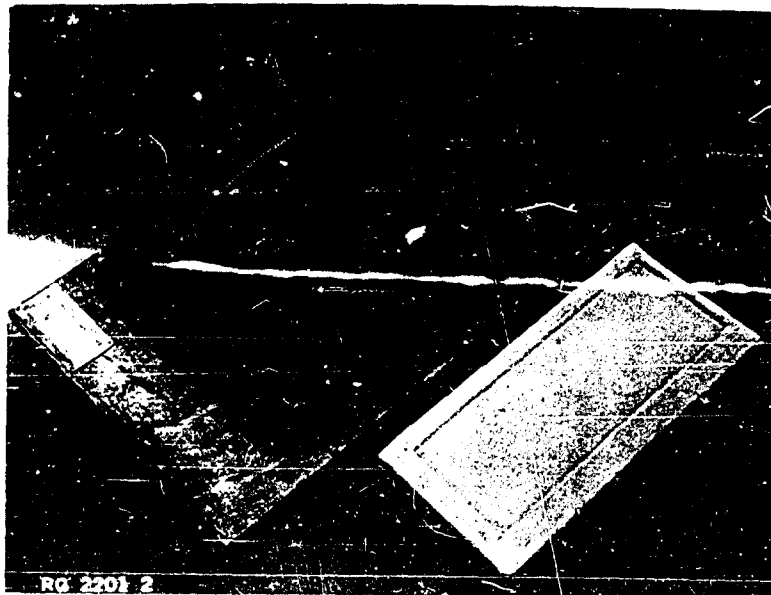
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CERAMIC TOOLS IN PRODUCTION



RG 2076 12

Fig. 25

Trimmed part before and after cleaning. Buildup on the uncleaned part is Thalco film and "dead" Teflon. The "dead" Teflon is usually removed after forming about three parts.

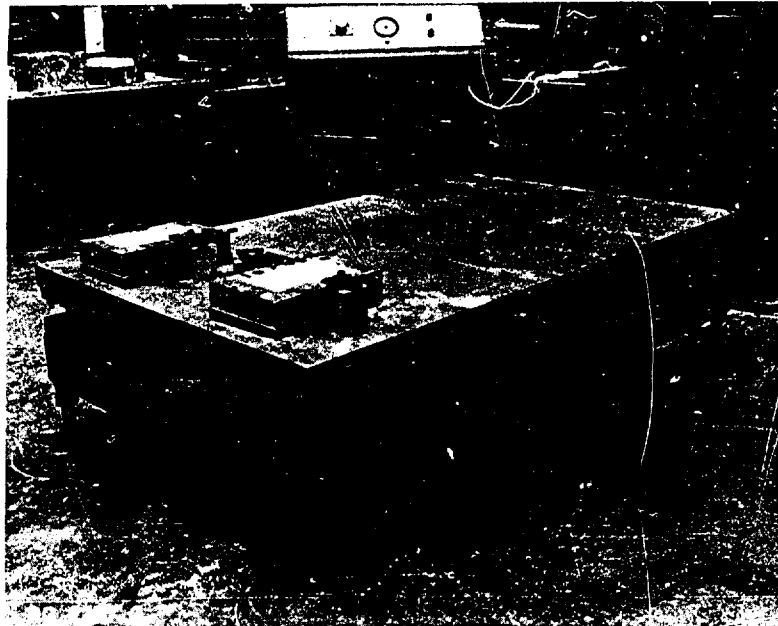


RG 2201 2

Fig. 26

Power assembly cover LUB and trimmed part.

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RG 2287 2

Fig. 27

Vibrating table and console. Brick size castings
are mounted for vibrating.

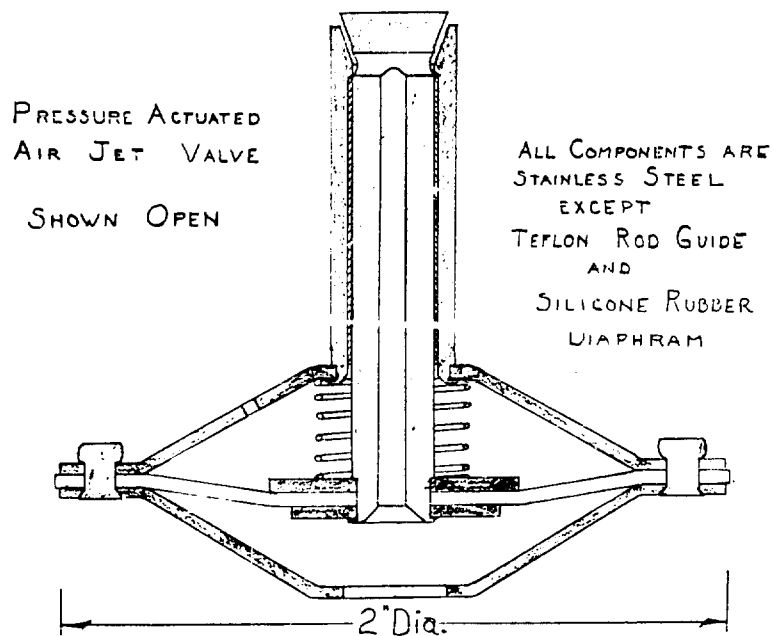


Fig. 28

New Air jet valve.